

National Aeronautics and Space Administration



# Implementing the Earth Science Flight Program

## Instrument Developments & Earth Venture

Dr. Stephen Volz  
Associate Director for Flight Programs  
Earth Science Division, Science Mission Directorate

# Outline of Presentation



- ◆ Flight Program Overview
- ◆ Phase C/D, Missions in Development
- ◆ Phase A/B, Missions in Formulation
- ◆ Pre-Phase A, Missions in Pre-Formulation
- ◆ 2011 Climate Initiative
- ◆ Accelerated Decadal Survey, New Climate Missions and
- ◆ Augmented Earth Venture Opportunities

# NASA Earth Science Efforts Concentrated in 6 Areas

- ◆ Planning, Building and operating Earth observing satellite missions, most with international and/or interagency partners
- ◆ Making high-quality data products available to the broad science community
- ◆ Conducting and sponsoring cutting-edge research in 6 thematic focus areas
  - Field campaigns to complement satellite measurements
  - Modeling
  - Analyses of non-NASA mission data
- ◆ Conducting an Applied Science program to improve the utilization of the data through the U.S.
- ◆ Developing technologies to improve Earth observation capabilities, providing the seed technologies for the next generation of earth observing instruments
- ◆ Education and Public Outreach

**Flight projects**

**Data Systems**

**Research &  
Analysis**

**Applied  
Science  
Earth Science  
Technology**

**E/PO**

# Missions Distributed by NASA Flight Project Life Cycle

Project Life Cycle						
Project Pre-Formulation	Project Formulation		Approval (For Implementation)	Project Implementation		
Pre-Phase A	Phase A	Phase B	Phase C	Phase D	Phase E	Phase F
<u>NASA:</u> DESDynI CLARREO SWOT ASCENDS ACE GEO-CAPE HypIRI <b>GRACE FO</b> <b>PACE</b>  <u>Reimbursable:</u> QuikSCAT FO	<u>NASA:</u> ICESat-2 <b>SAGE III</b>	<u>NASA:</u> <b>SMAP</b> <b>OCO-2</b> Venture EV-1	<u>NASA:</u> NPP Glory Aquarius GPM LDCM	<u>NASA Prime:</u> Aura OSTM  <u>NASA Extended:</u> Aqua Terra TRMM Jason EO-1 QuikSCAT SORCE Acrimsat CALIPSO CloudSat GRACE		

**BLUE** indicates Decadal Survey activities  
**GREEN** indicates Climate enabled by new budget



National Aeronautics and Space Administration



## Phase C/D: Missions In Development

# Earth Science Missions in Development

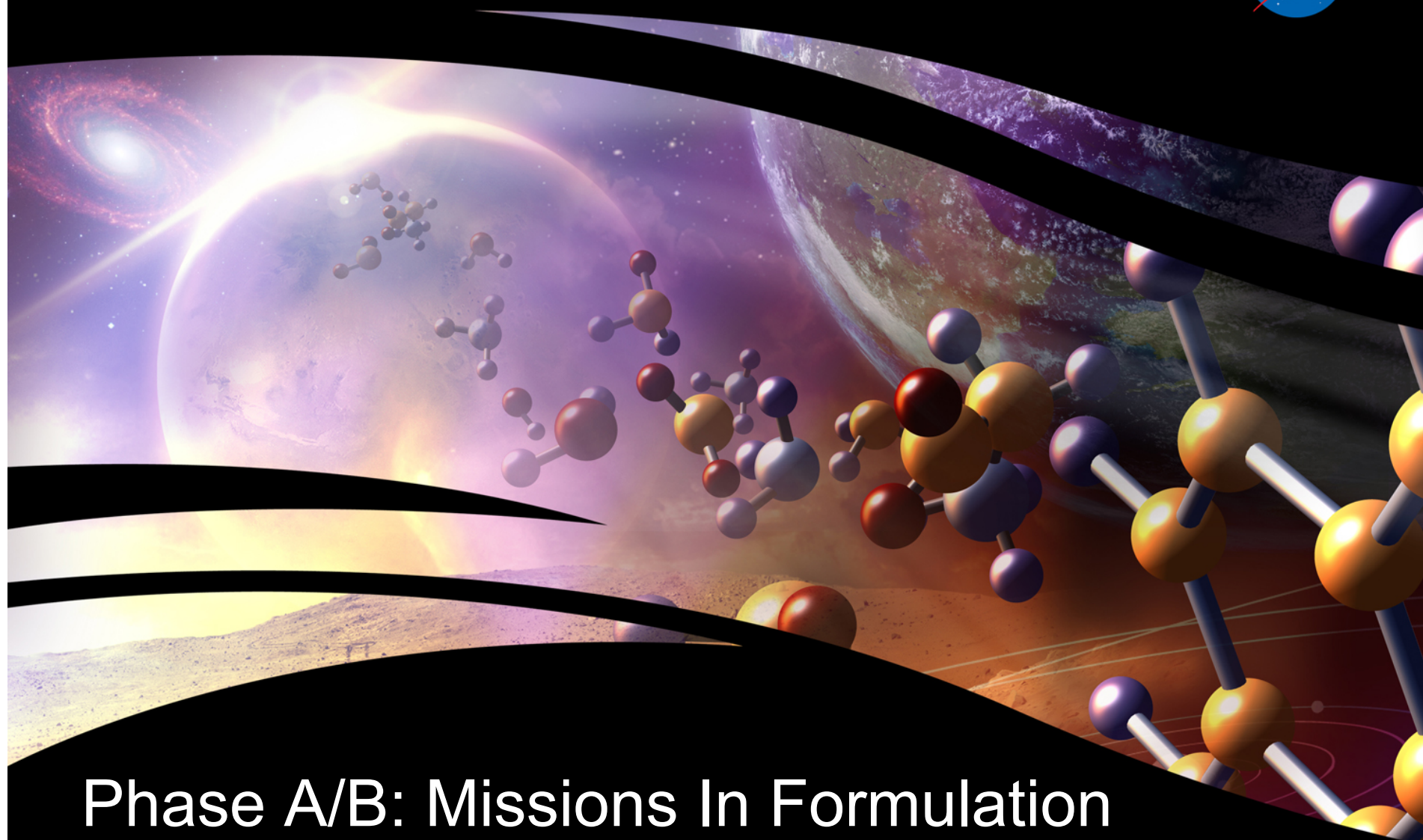


<b>NPOESS Preparatory Project<sup>1</sup></b> Strategic mission – Systematic measurement	Required for continuity of several key climate measurements between EOS and NPOESS
<b>Glory</b> Strategic mission – Initiate New Measurement and Continue Systematic Measurement	Addresses high priority objective of the US Climate Change Science Program and provide continuity for total solar irradiance
<b>Aquarius<sup>2</sup></b> Competed mission – Earth System Science Pathfinder	First dedicated global measurement of sea surface salinity from space
<b>LDCM<sup>1</sup></b> Strategic mission – Systematic measurement	Continues the 30+ year Landsat moderate resolution multispectral land imaging data record; includes new high sensitivity thermal instrument TIRS
<b>Global Precipitation Measurement<sup>2</sup></b> Strategic Mission – Systematic measurement	Measure rain microphysical properties and vertical structure, Improve weather, climate, and hydrologic predictions and water resource management

<sup>1</sup> Represents Interagency Partnership

<sup>2</sup> Represents International Partnership

National Aeronautics and Space Administration



Phase A/B: Missions In Formulation



# Earth Science Missions in Formulation



<b>Orbiting Carbon Observatory – 2</b> Directed reflight of lost OCO mission.	First dedicated global measurement of CO <sub>2</sub> from space
<b>Soil Moisture Active/Passive Mission</b> 1 <sup>st</sup> Decadal Survey mission – Systematic measurement	Will use a combined radiometer and high-resolution radar to measure globally surface soil moisture and freeze-thaw state.
<b>Earth Venture – 1 (EV-1) AO</b> 1 <sup>st</sup> Decadal Survey Venture class announcement	Complete suborbital, principal investigator-led investigations to conduct innovative, integrated, hypothesis or scientific question-driven approaches to pressing Earth system science issues
<b>Ice Cloud and land Elevation Satellite – 2, ICESat-2</b> Systematic measurement and 2 <sup>nd</sup> Decadal Survey mission	Will measure the dynamic state of the Earth's ice sheets, their seasonal and annual variations and volumetric change



National Aeronautics and Space Administration



# Mission Studies in Pre-Formulation

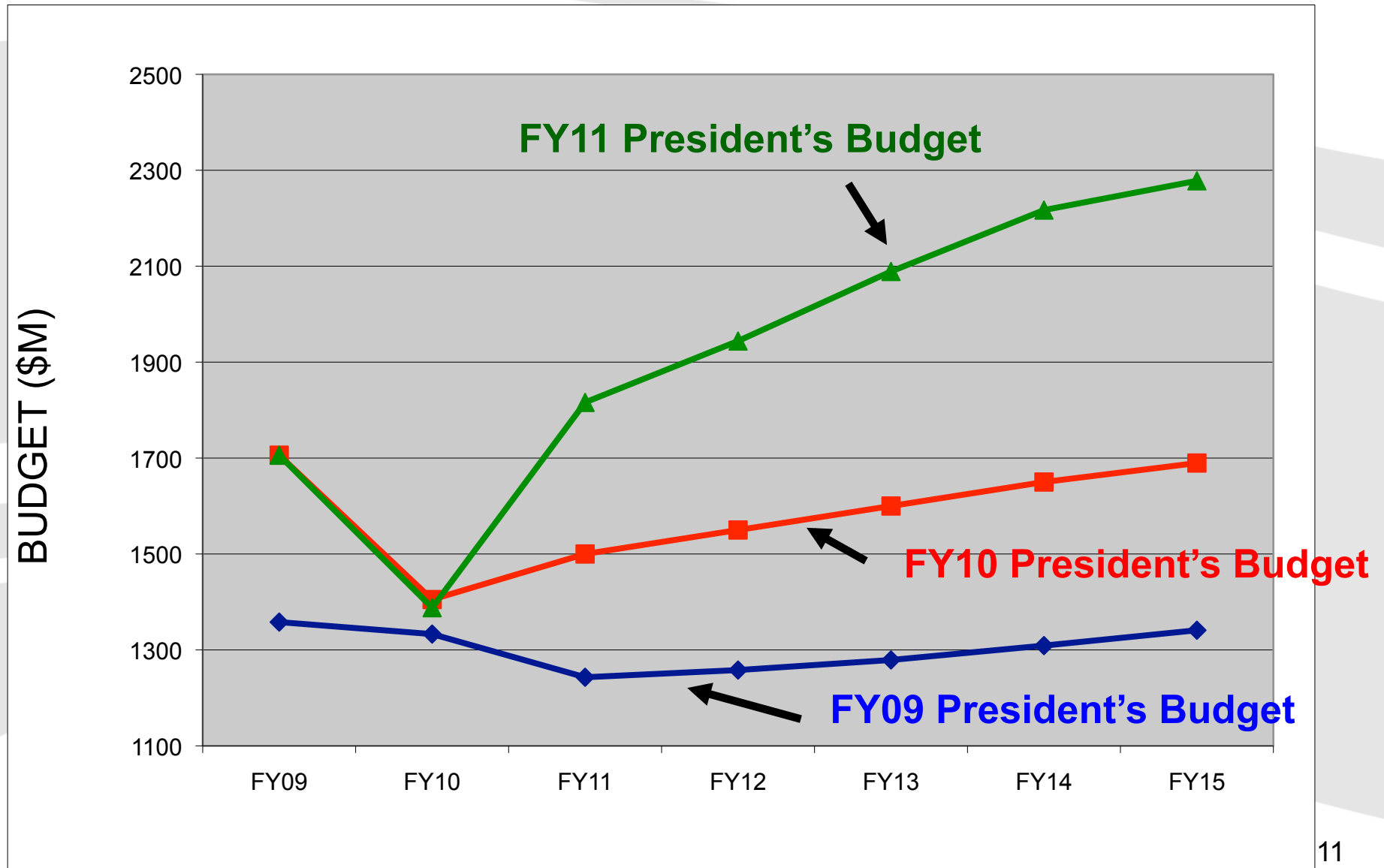
# ESD Implementation Approach – Prior to the Climate Initiative



- ♦ We are working to develop a Program, not just fly individual missions, and are flying 1-2 missions every year well into the next decade
- ♦ Complete the foundational missions as planned and as fast as possible
  - 2010: Aquarius & Glory (\$700M)
  - 2011: NPP (\$900M)
  - 2012: LDCM (\$950M)
  - 2013: GPM (\$1,000M)

Venture Class calls – 2009, 2011, 2012, ...
- ♦ Complete the Decadal Survey 1<sup>st</sup> Tier missions as quickly as possible
  - 2014: SMAP (\$700M)
  - 2015: ICESat-2 (\$750M)
  - 2019: DESDynI (>\$1,000M/TBR)
  - 2019: CLARREO (\$900M/TBR)

# President's FY2011 Budget for Earth Science



# EARTH AUGMENTATION ALLOCATIONS



	FY11	FY12	FY13	FY14	FY15	TOTAL
Base	1495	1544	1589	1617	1632	7877
OCO-2	171	91	51	13	4	330
<b>Climate Initiative</b>	150	309	449	587	646	2141
<b>Initiative Distribution Between Flight and Non-Flight</b>						
Climate Non-Flight	50	75	90	110	125	450
Climate Flight	100	234	359	477	521	1691

All figures in \$M

- ♦ Initiative and additional funds specified that a broad climate based response was required, much more than simply accelerating the Decadal Survey missions



# ESD *Climate* Implementation Approach



- ♦ We are working to develop a Program, not just fly individual missions, and are flying 1-2 missions every year well into the next decade

- ♦ Complete the foundational missions as planned

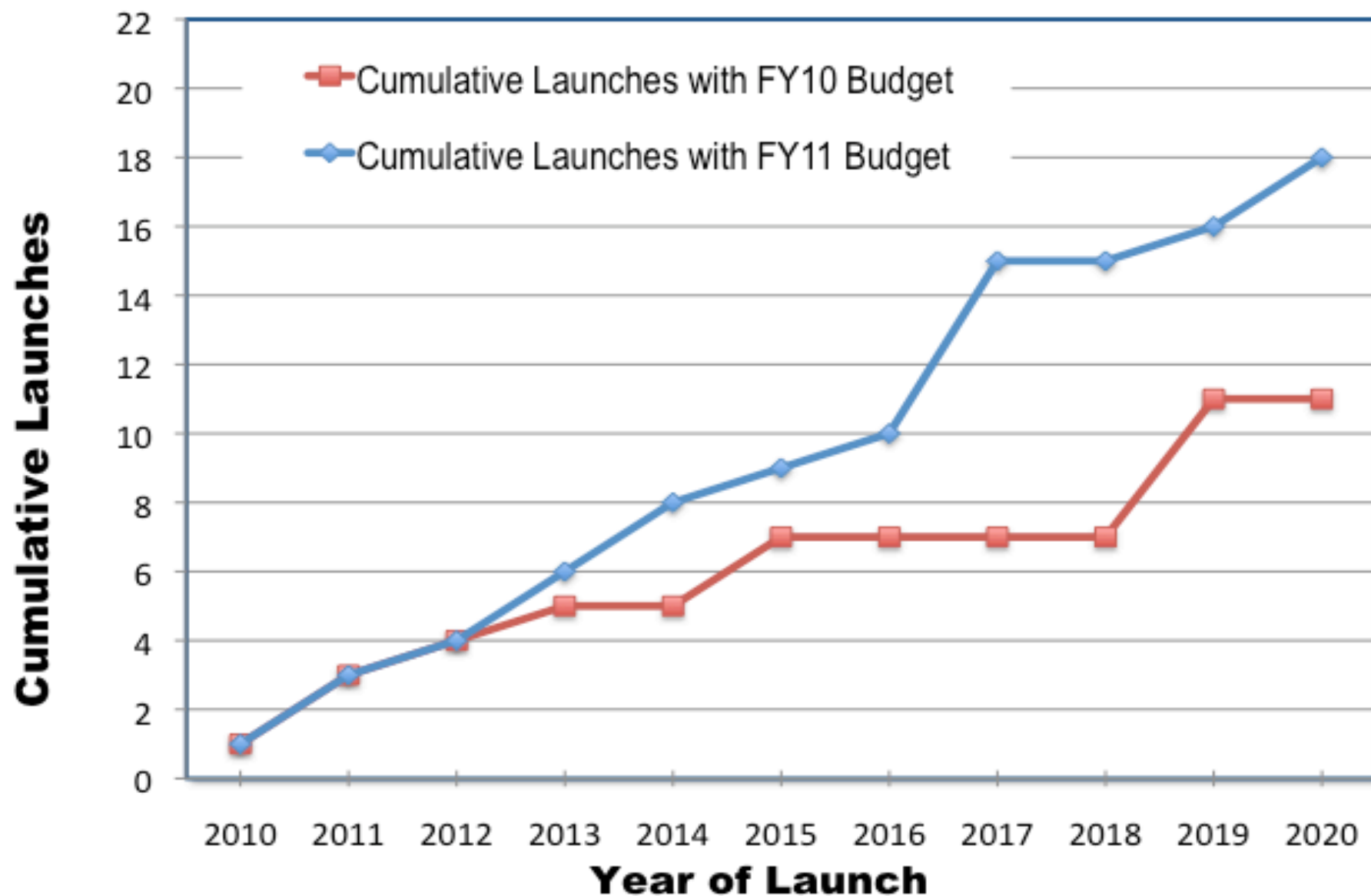
2010: Glory (\$450M)  
2011: Aquarius & NPP (\$1,300M)  
2012: LDCM (\$950M)  
2013: GPM (\$1,000M)

Venture Mission Class calls – 2009, 2011, 2013, ...  
Venture Instrument calls – 2011, 2012, 2013, ...

- ♦ Complete the DS 1<sup>st</sup> Tier missions by 2017, and move out with DS 2<sup>nd</sup> Tier and Climate Missions

2013: OCO-2 (\$330M)  
2014: SMAP & SAGE III (\$900M)  
2015: ICESat-2 (\$750M)  
2016: GRACE FO (\$375M)  
2017: DESDynI, CLARREO-1 & EV-2 (\$2,300M)  
2019: PACE (\$900M)  
2020: CLARREO-2, ASCENDS & SWOT (\$1,300M)

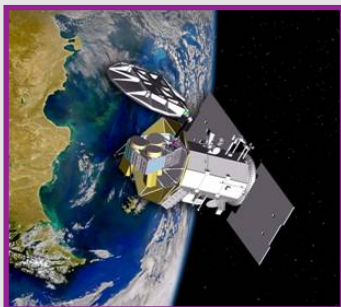
# More Earth Observing Satellites Launched



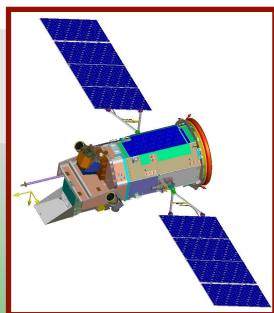
# ESD Missions in Pre-Formulation thru 2020



## Phase A



SAGE III 2014



GRACE FO  
2016



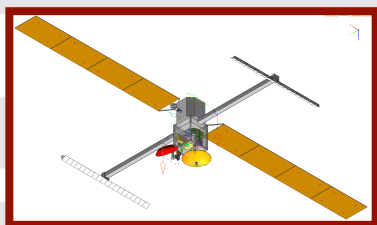
DESDynI  
Lidar & Radar  
2017



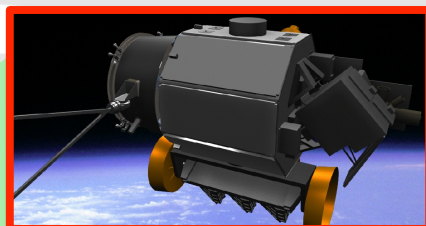
CLARREO-1  
2017



EV-2  
2017



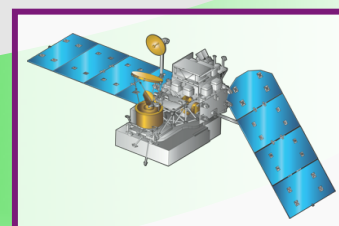
SWOT  
circa 2020



CLARREO-2  
2020

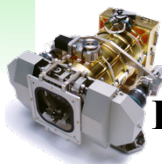


ASCENDS  
circa 2020

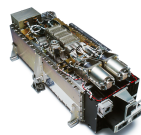


PACE  
circa 2019

Instrument  
Developments



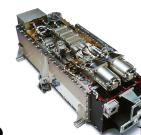
EV-I4  
2019



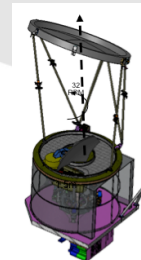
EV-I3  
2018



EV-I2  
2017



EV-I1  
2016



GMI#2  
2013

# Decadal Survey Mission Development Status



Climate Absolute Radiance and Refractivity Observatory (CLARREO)

**Formulation In FY2011**



Soil Moisture Active Passive (SMAP)

**Formulation Development in FY2011**

Ice, Cloud, and Land Elevation Satellite II (ICESat-II)

**Formulation**



Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI)

**Formulation In FY2011**

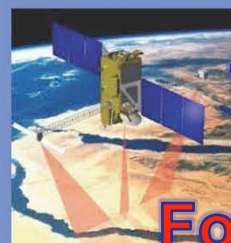
Tier I



Hyperspectral Infrared Imager (HYSPIRI)

Active Sensing of CO<sub>2</sub> Emissions (ASCEES)

**At least two**



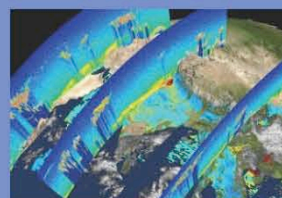
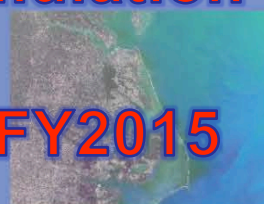
Surface Water and Ocean Topography (SWOT)

**to be in**

**Formulation**

Geostationary Coastal and Air Pollution Events (GEO-CAPE)

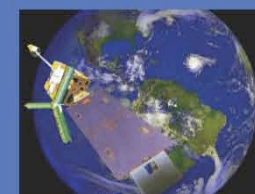
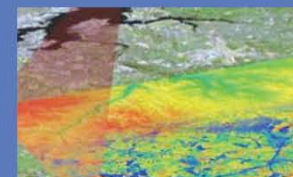
**By FY2015**



Aerosol - Cloud - Ecosystems (ACE)

Tier II

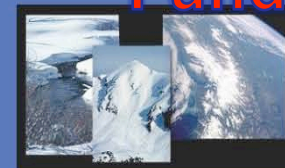
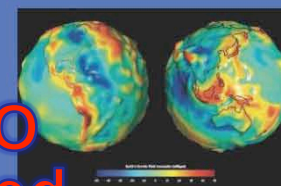
LIDAR Surface Topography (LIST)



Precipitation and All-Weather Temperature and Humidity (PATH)

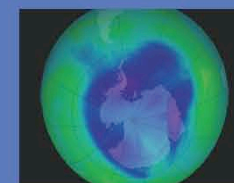
Gravity Recovery and Climate Experiment - II (GRACE - II)

**ESTO Funded**



Snow and Cold Land Processes (SCLP)

Three-Dimensional Winds from Space Lidar (3D-Winds)

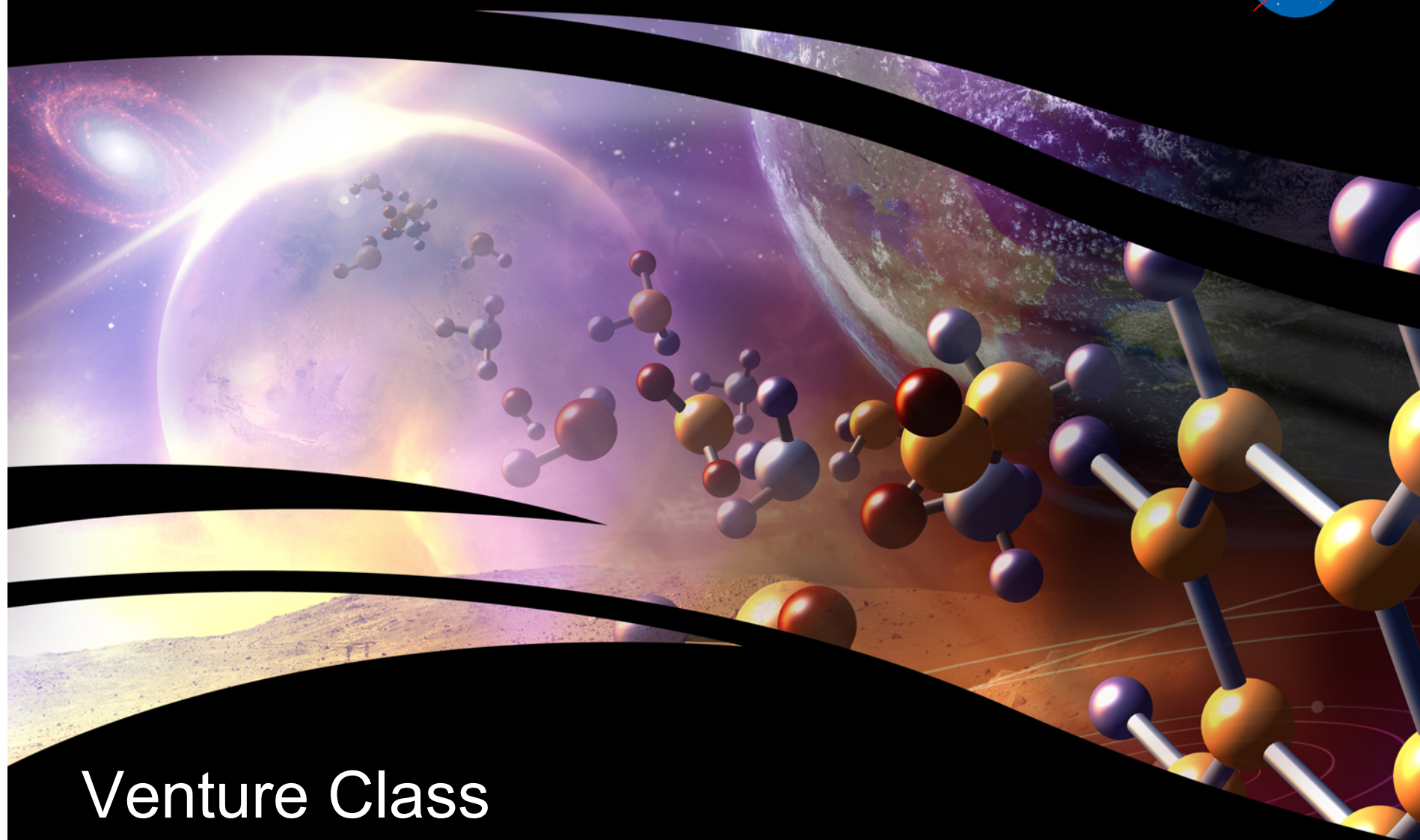


Global Atmospheric Composition Mission (GACM)

Tier III



National Aeronautics and Space Administration



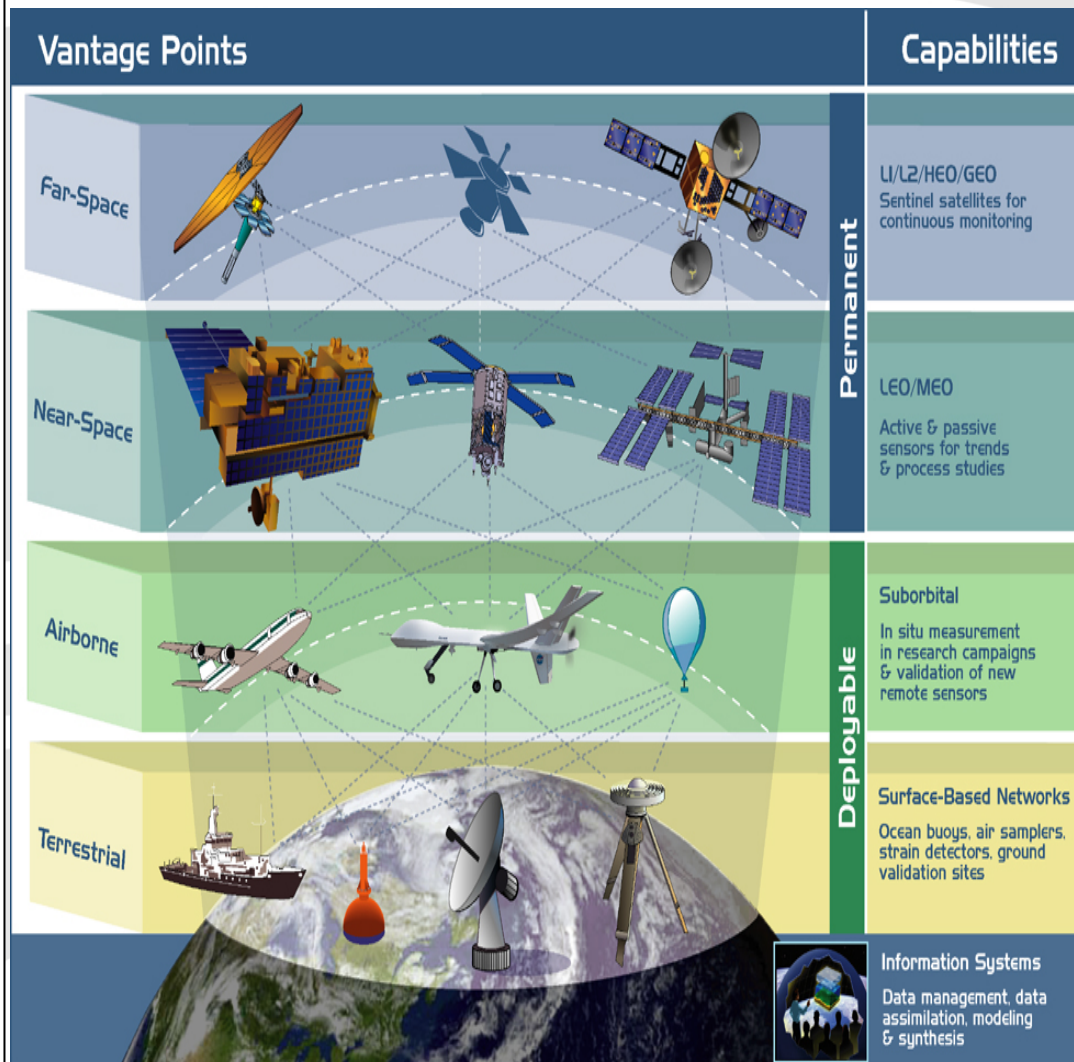
# Venture Class

# Earth Science Observations are more than Satellites



- ◆ Airborne, for observations, instruments, and simulators
- ◆ Advanced instrument and technology investments for future satellite hardware
- ◆ Ground calibration of instruments for better absolute accuracy
- ◆ Airborne and ground sites for flight validation
- ◆ Effective interagency partnerships have been utilized in each of these areas

# Airborne and Ground-Based Measurement Programs



♦ Airborne science assets are actively engaged in the mission definition and development activities

- ❑ Instrument development flights supporting mission definition (DESDynI and ASCENDS)
- ❑ Data gathering as gap fillers (ICESat-2)
- ❑ Test beds for IIP missions

# ESSP-based Venture Class Mission line



**Venture missions will be aligned to the recommendations of the National Academy of Science 2007 Decadal Survey:**

- ◆ Restore more frequent launch opportunities
- ◆ Foci:
  - Measurement and observation innovation
  - Demonstration of innovative ideas and higher-risk technologies
  - Establish new research avenues
  - Demonstrate key application-oriented measurements
- ◆ May include:
  - stand-alone missions that use simple, small instruments, spacecraft, and launch vehicles;
  - more complex instruments of opportunity flown on partner spacecraft and launch vehicles; or
  - complex sets of instruments flown on suitable suborbital platforms
- ◆ ***“...Key to the success ...will be maintaining a steady stream of opportunities for community participation in the development of innovative ideas, which requires that strict schedule and cost guidelines be enforced ...”***



# Features of Venture Mission Line



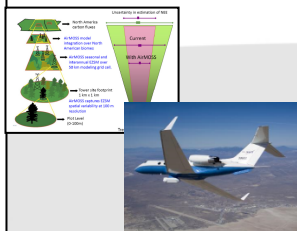
- ◆ Venture will address **exploratory** science. “Named” missions are directed and covered within the Earth Systematic Missions program
- ◆ Yearly calls as recommended by the NRC decadal survey
  - AO driven, competitively selected, PI-led projects, with science potentially be open to all earth science themes
- ◆ Optimal mix of sub-orbital, instrument and orbital mission opportunities
  - Alternate between orbital and sub-orbital for yearly calls
- ◆ Completion schedule required in less than 5 years from award
  - Key Decision Points will gauge performance *and continued funding*
- ◆ Projects will be cost capped
  - Total orbital mission project Life Cycle Cost of \$90M - \$150M
  - Multiple sub-orbital awards executed within same yearly budget
- ◆ Space-based calls will allow possible overlaps with decadal survey strategic missions, if they meet the other criteria (innovation, cost, schedule and science driven)
- ◆ First Earth Venture -1 (EV-1) call for airborne campaigns selection in Spring 2010.
- ◆ Subsequent calls planned for FY2011, with awards in FY2012

# Earth Venture – 1 (EV-1) Investigations



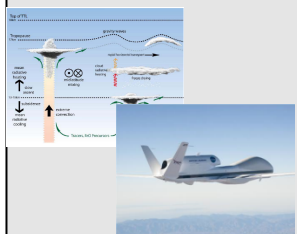
- ◆ The first set of Venture-class investigations, or Earth Venture-1 (EV-1), solicited proposals for complete suborbital, principal investigator-led investigations to conduct innovative, integrated, hypothesis or scientific question-driven approaches to pressing Earth system science issues
  - **Sustained, science-based data acquisition** — The investigations must advance Earth system science objectives through temporally sustained regional- or larger-scale measurements sufficient and necessary to prove/disprove a scientific hypothesis or address scientific questions.
  - **Mature technology** — The investigations must use mature system technology where, at a minimum, there has been a system/sub-system model or prototype demonstration in a relevant environment (Technology Readiness Level (TRL) of 6 or greater).
  - **Competitive selection** — The investigations will be selected in an open competition, to ensure broad community involvement and encourage innovative approaches.
  - **Cost and schedule constraints** — Each suborbital Venture-class investigation must have a life cycle of less than or equal to 5 years and total investigation cost not to exceed \$30 million.
- ◆ EV-1 winners announced in May 2010

# EARTH VENTURE-1 SELECTION Summaries



## Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) - Univ Mich/JPL

North American ecosystems are critical components of the global exchange of the greenhouse gas carbon dioxide and other gases within the atmosphere. To better understand the size of this exchange on a continental scale, this investigation addresses the uncertainties in existing estimates by measuring soil moisture in the root zone of representative regions of major North American ecosystems. Investigators will use NASA's Gulfstream-III aircraft to fly synthetic aperture radar that can penetrate vegetation and soil to depths of several feet.



## Airborne Tropical Tropopause Experiment (ATTREX) - ARC

Water vapor in the stratosphere has a large impact on Earth's climate, the ozone layer and how much solar energy the Earth retains. To improve our understanding of the processes that control the flow of atmospheric gases into this region, investigators will launch four airborne campaigns with NASA's Global Hawk remotely piloted aerial systems. The flights will study chemical and physical processes at different times of year from bases in California, Guam, Hawaii and Australia.



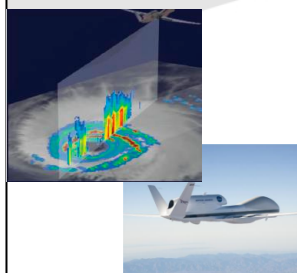
## Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) - JPL

This investigation will collect an integrated set of data that will provide unprecedented experimental insights into Arctic carbon cycling, especially the release of the important greenhouse gases such as carbon dioxide and methane. Instruments will be flown on a Twin Otter aircraft to produce the first simultaneous measurements of surface characteristics that control carbon emissions and key atmospheric gases.



## Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) - LaRC

The overarching objective of the DISCOVER-AQ investigation is to improve the interpretation of satellite observations to diagnose near-surface conditions relating to air quality. NASA's B-200 and P-3B research aircraft will fly together to sample a column of the atmosphere over instrumented ground stations.



## Hurricane and Severe Storm Sentinel (HS3) – GSFC/ARC

The prediction of the intensity of hurricanes is not as reliable as predictions of the location of hurricane landfall, in large part because of our poor understanding of the processes involved in intensity change. This investigation focuses on studying hurricanes in the Atlantic Ocean basin using two NASA Global Hawks flying high above the storms for up to 30 hours. The Hawks will deploy from NASA's Wallops Flight Facility in Virginia during the 2012-14 Atlantic hurricane seasons.

# Earth Venture – 2 (EV-2) Investigations



- ◆ The second call for Venture-class investigations, or Earth Venture-2 (EV-2), will solicit proposals for a complete, principal investigator-led mission to conduct innovative, integrated, hypothesis or scientific question-driven approach to pressing Earth system science issues
  - **Sustained, science-based data acquisition** — The successful investigation must advance Earth system science objectives through a focused orbital measurement of sufficient clarity and breadth to prove/disprove a scientific hypothesis or address scientific questions.
  - **Mature technology** — All proposed investigations must use mature system technology where, at a minimum, there has been a system/sub-system model or prototype demonstration in a relevant environment (Technology Readiness Level (TRL) of 6 or greater).
  - **Competitive selection** — The investigations will be selected in an open competition, to ensure broad community involvement and encourage innovative approaches. We expect to use a two step AO evaluation process.
  - **Cost and schedule constraints** — The successful proposal must be accomplished a life cycle from initiation to launch in less than 5 years and a total life cycle cost not to exceed \$150M, including reserves.
- ◆ EV-2 Announcement of Opportunity to be made Spring 2011, with the winning selection in early FY2012



# EV-2 Mission Scope & Parameters



## ♦ Science Scope

- ❑ The initial AO will have an open science call.
- ❑ The mission is not intended to replace or advance individual Decadal Survey missions, however they can address portions of mission science

## ♦ Schedule

- ❑ The mission must have a life cycle of less than or equal to 5 years to launch and total investigation cost not to exceed \$150 million, including operations and data analysis

## ♦ Evaluation Criteria

- ❑ Science and mission feasibility are both critical.
- ❑ Technology development is not expected.

## ♦ Partnerships

- ❑ Enabling partnerships are encouraged, but the stability & reliability of the partnership will be considered as a risk element in the proposal
- ❑ Hosting an instrument on the ISS or on a partner-provided satellite are acceptable, but the partnership must be established in the proposal

# EV-Instruments (EV-I) – Scope of Program



- ◆ The third leg of the Venture-class investigations, or Earth Venture-Instruments (EV-I), will solicit proposals for a complete, principal investigator-led instrument to conduct innovative, integrated, hypothesis or scientific question-driven approach to pressing Earth system science issues
  - ❑ Annual series of Instrument-Only solicitations, beginning in FY2011 with the 1<sup>st</sup> selection in FY2012
  - ❑ One-step SALMON solicitation. The investigations will be selected in an open competition, to ensure broad community involvement and encourage innovative approaches.
  - ❑ Cost capped approach, notionally \$90M per solicitation. More than one instrument may be selected within one solicitation.
  - ❑ Instruments will be flown on domestic and international flights of opportunity
  - ❑ Instrument will strive to use a common instrument interface, with the interface requirements developed by the ESSP and defined in the AO.
- ◆ The PI will retain a central role on the instrument when it is finally manifested and flown

# EV-I Opportunities and Plans



## ♦ Science Scope

- ❑ The initial AO will have an open science call, no restrictions.
- ❑ The instruments are is not intended to replace or advance individual Decadal Survey missions, however they can address portions of mission science, or could be precursor measurements for DS missions

## ♦ Cost & Schedule

- ❑ The instrument(s) development time should be up to 4 years from award and must have a life cycle cost not to exceed \$90 million.

## ♦ Evaluation Criteria

- ❑ Science and instrument technical feasibility are both critical.
- ❑ Technology development is allowable, but only if the integrated instrument development risk still fits within the schedule and cost.

## ♦ Partnerships

- ❑ The proposal does not have to bring a confirmed host mission with it, however suggested or proposed manifests are allowed.
- ❑ The ESD will negotiate flight opportunities



EV Schedule	Type	Solicitation	Selection	Launch/Delivery
EV-1	Suborbital	2009	2010	
EV-2	Full Orbital	2011	2012	LRD ~2017
EV-I1	Instrument Only	2011	2012	Del ~2016
EV-I2	Instrument Only	2012	2013	Del ~2017
EV-3	Suborbital	2013	2014	
EV-I3	Instrument Only	2013	2014	Del ~2018
EV-I4	Instrument Only	2014	2015	Del ~2019
EV-4	Full Orbital	2015	2016	LRD ~2021
EV-I5	Instrument Only	2015	2016	Del ~2020
EV-I6	Instrument Only	2016	2017	Del ~2021

## ***PPBE 2012 Earth Venture Mission Schedule***